Controllable Inflatable Aeroshell

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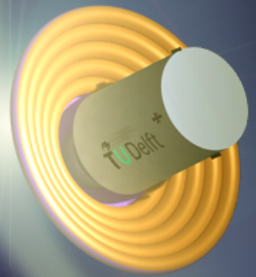

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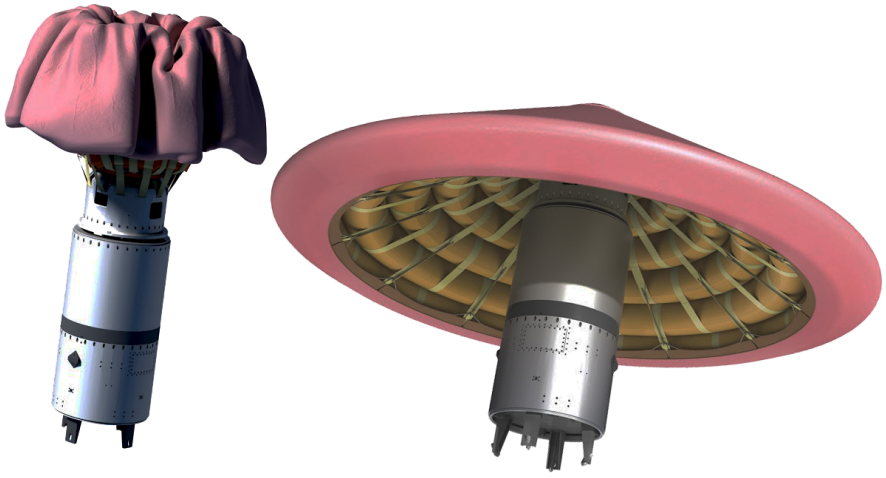
Current limitations for EDL

Why do we need an Aeroshell?

- MSL pushing the physical limits
  - Payload mass
  - Size of the vehicle

- Decelerate interplanetary probe
  - Robotic missions
  - Manned missions to Mars



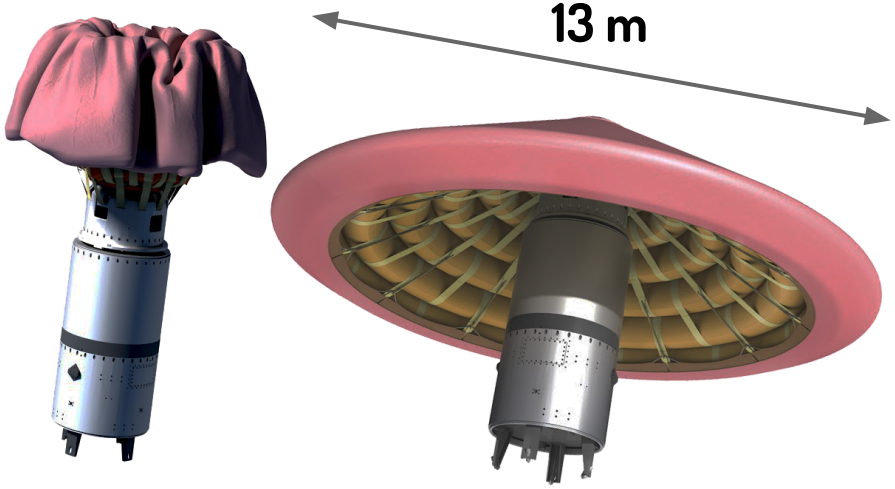
Courtesy: NASA - IRVE-3

The Design Conditions

Max. G-load **5.2 g**

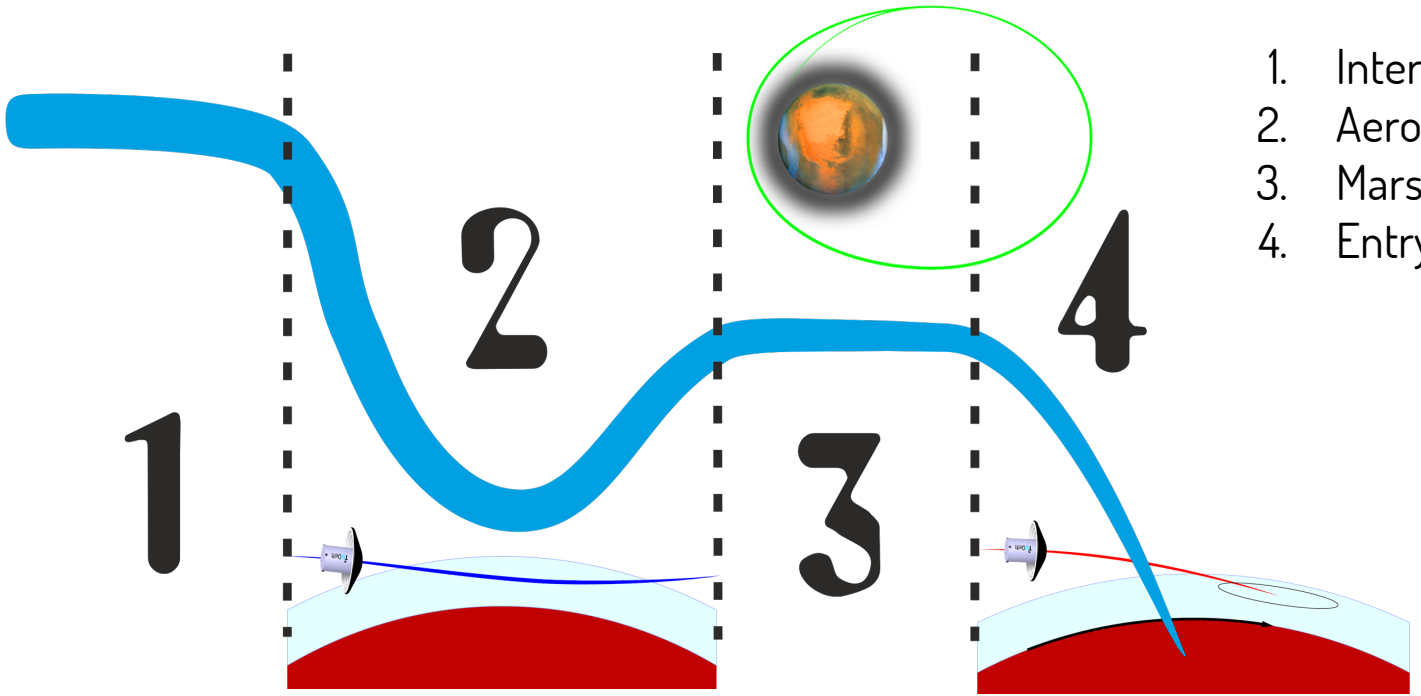
Mass **10 tons**
(10% for aeroshell)

Entry speed **7000 m/s**



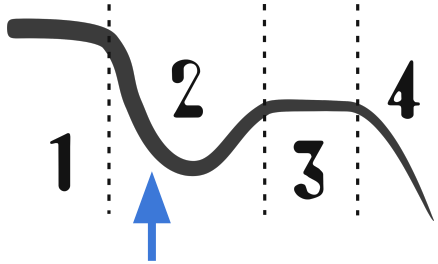
Courtesy: NASA - IRVE-3

Mission Phases



1. Interplanetary Trajectory
2. Aerocapture
3. Mars Synchronous Orbit
4. Entry, Descent to Landing

Aerocapture - Design Drivers



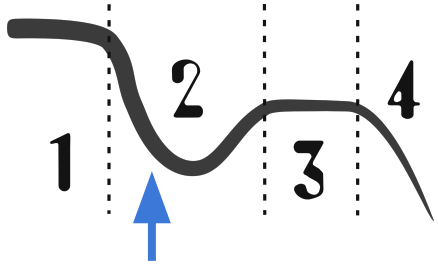
Entry conditions

- Interplanetary orbit

Exit conditions

- Successful aerocapture
- Mars synchronous elliptical orbit

Aerocapture - Design Drivers



Entry conditions

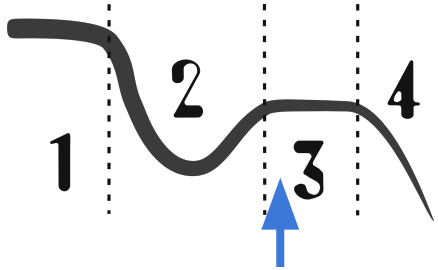
- Interplanetary orbit

Exit conditions

- Successful aerocapture
- Mars synchronous elliptical orbit

V_{entry} = **7000 m/s** → $V_{exit} < 4950$ m/s

Aerocapture - Design Drivers



Chosen exit velocity:

$$V_{exit} = 4715.5 \text{ m/s}$$

Safety vs Mass

- Minimize perigee raise burn

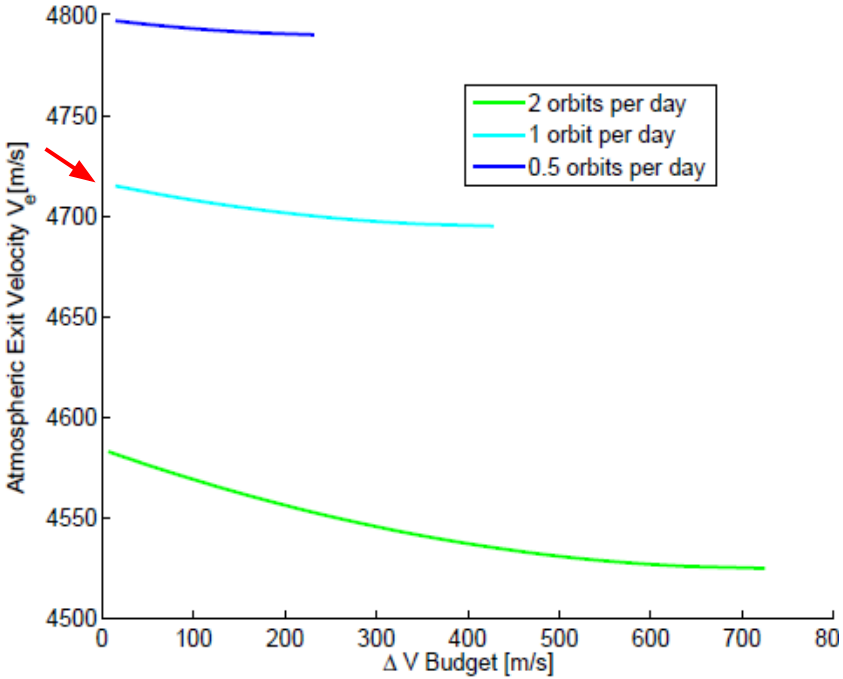


Figure 3-7: Exit velocity vs Δ V for r_p 200

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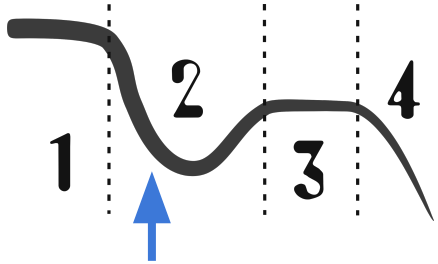
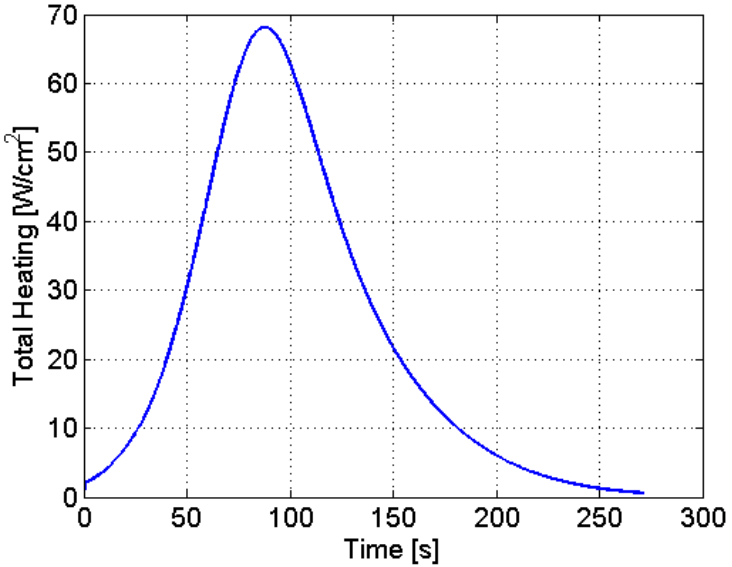
Aerocapture - Design Drivers





Downward leg

- Peak loads on the thermal protection system

  68.1 W/cm²

- At time of research

  20 W/cm²

- Future research

  150 W/cm²

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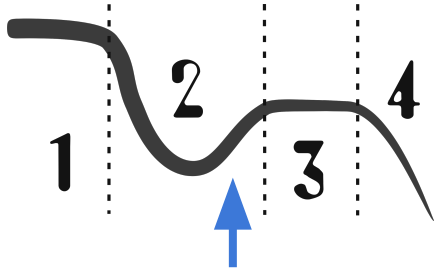
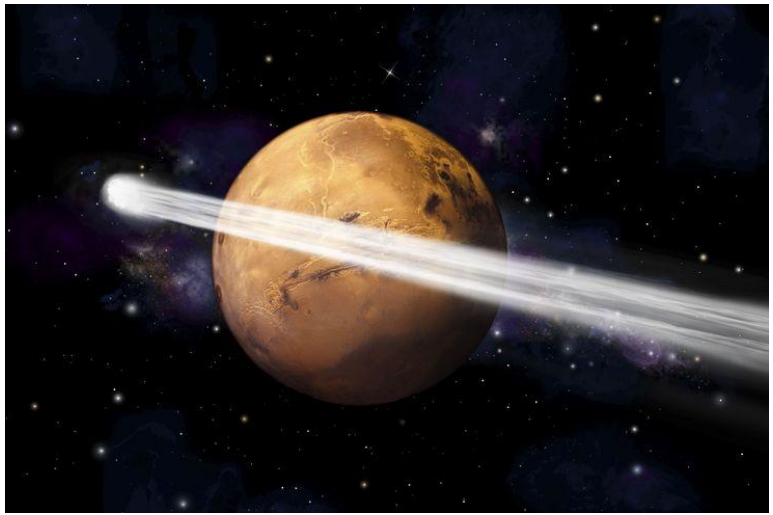
Aerocapture - Design Drivers



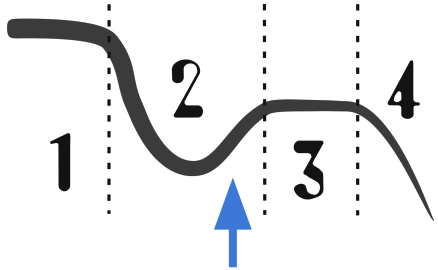
Exit conditions

- Crucial
    - Density variations of 100 %
    - Skip out

Extensive control and tracking required



Aerocapture - Design Drivers



Exit conditions

- Crucial
  - Density variations of 100 %
  - Skip out

Extensive control and tracking required

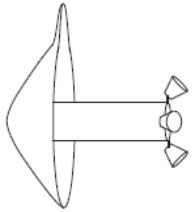
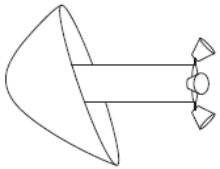
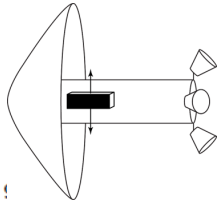
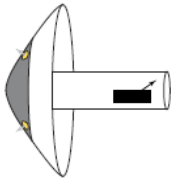
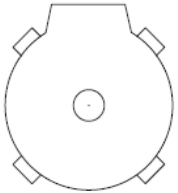
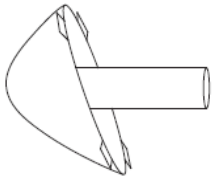
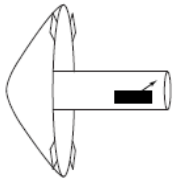
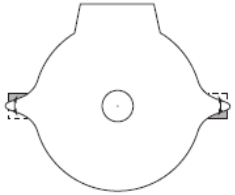
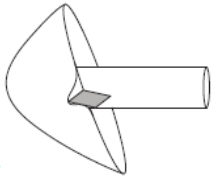
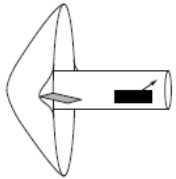
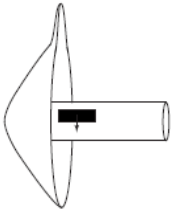
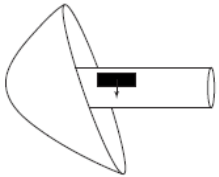
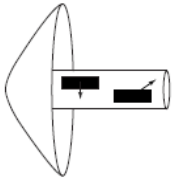
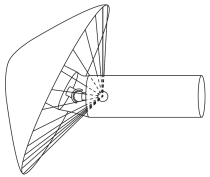
Solutions

- Margins included
- Decoupled vertical and horizontal control

➢ Two mechanisms required

LIFT

CONTROL

Control ↓ Lift →	Trim Tab	Oblique	CG-offset	CG-offset
Thrusters	1 	5 	9 	13 
Trim Tabs	2 	6 	10 	
Control surfaces	3 	7 	11 	
CG-offset	4 	8 	12 	

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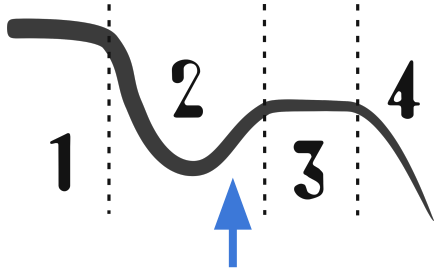
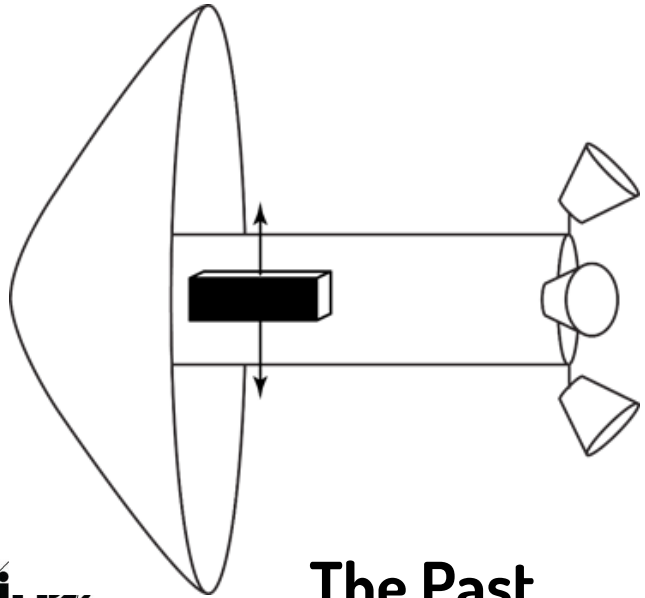
Aerocapture - Design Solutions



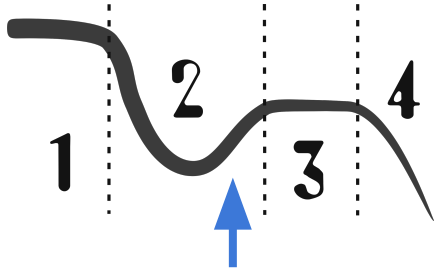
Internal CG shift + thrusters



The Past

The Future

Aerocapture - Design Solutions



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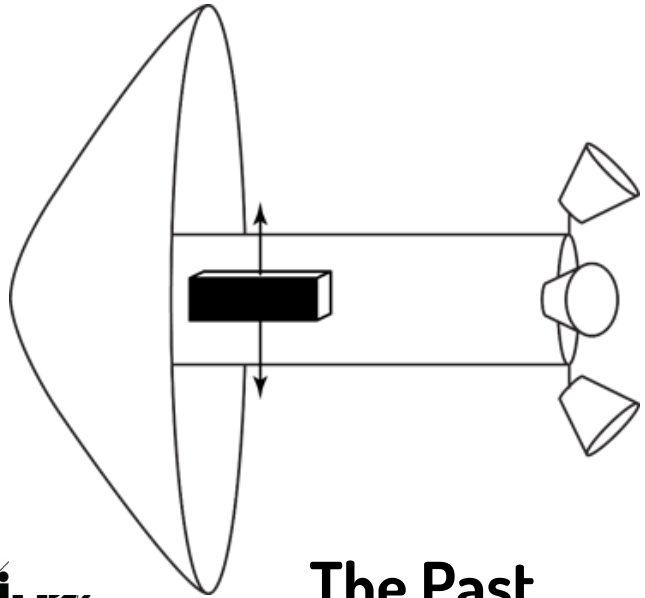
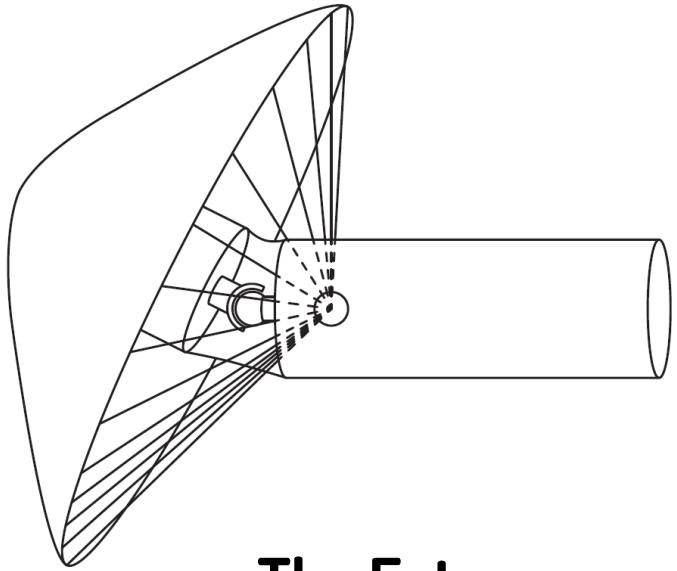


The Past

External CG shift



The Future

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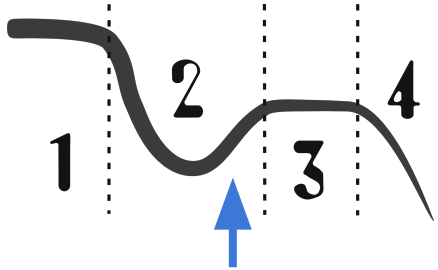
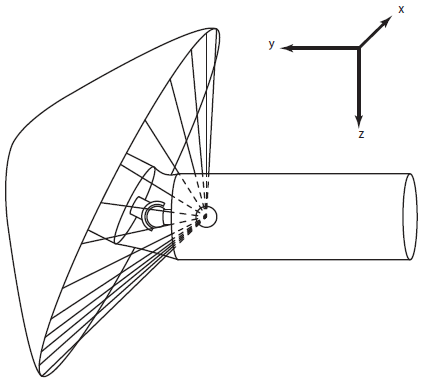
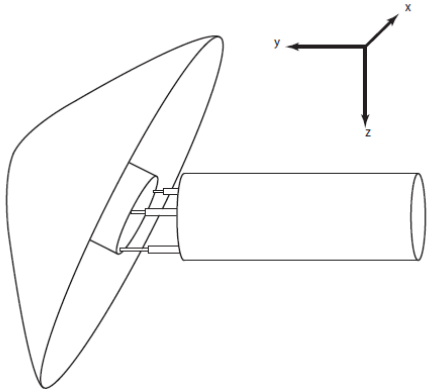
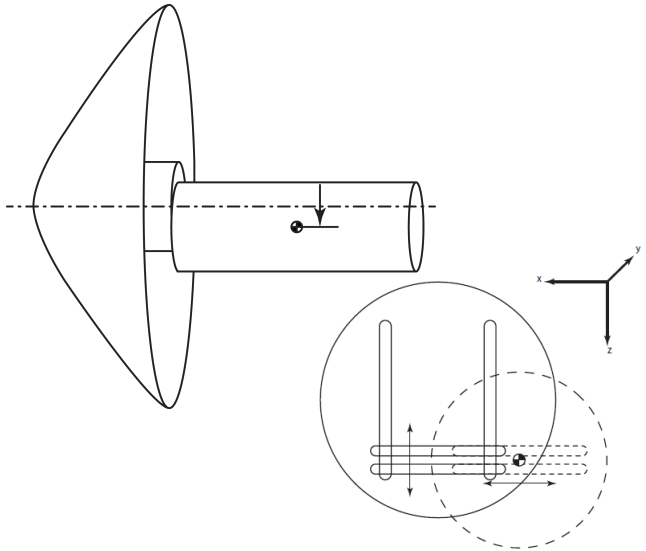
Aerocapture - Design Drivers



External CG shift







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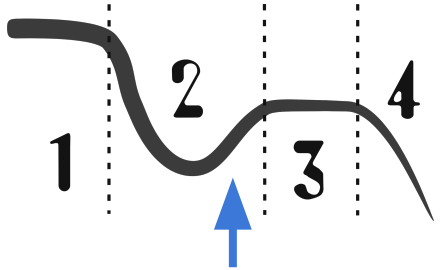
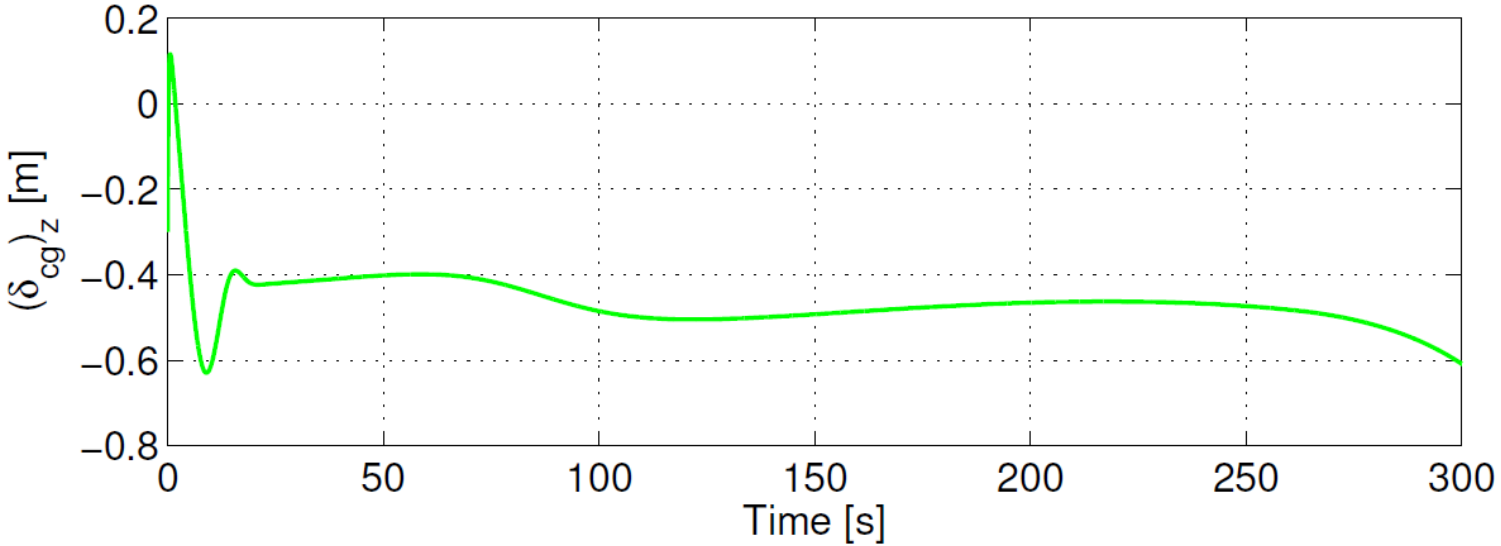
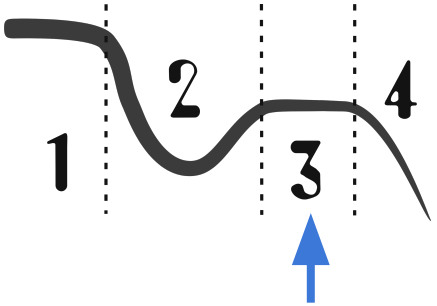
Aerocapture - Flight Path controller

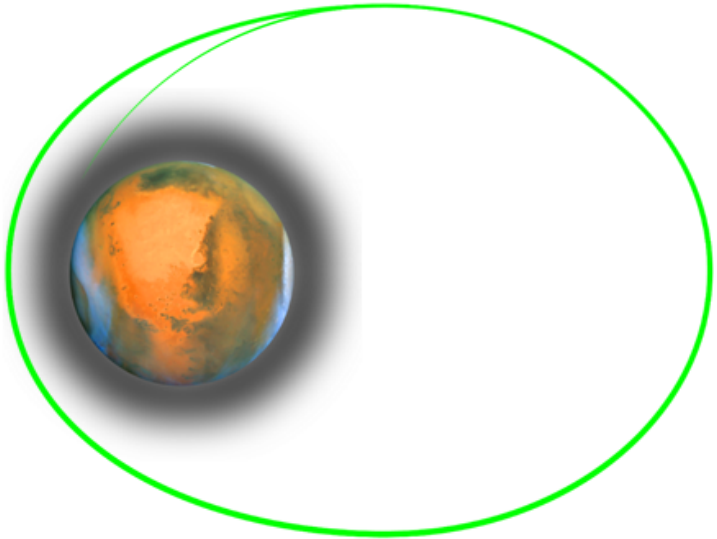


Vertical CG – shift during aerocapture

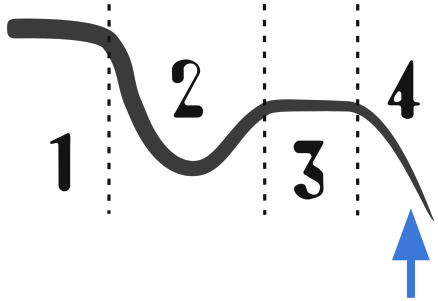


Mars Synchronous Orbit





EDL - Design Drivers



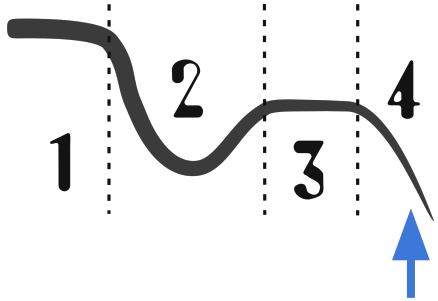
Entry conditions

- Lowered Mars synchronous elliptical orbit
  - V_{entry} = 4715.3 m/s
  - γ_{entry} = −11.55 deg

Goal conditions

- Target energy level
  - Height → h = 13 000 m
  - Velocity → V = 1.8 Mach

EDL - Design Drivers



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Critical loads

- Maximum g-load
- Reaching target energy level

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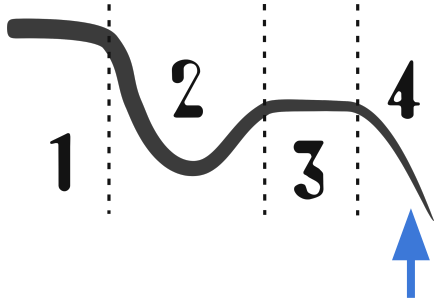
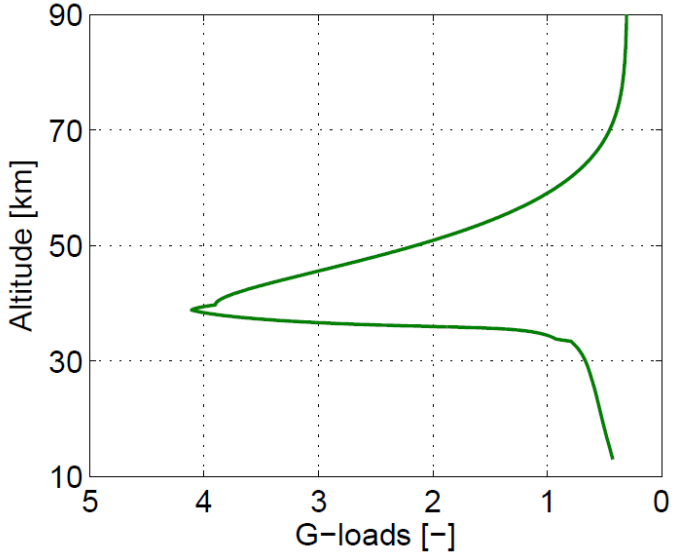
EDL - Design Drivers





Critical loads

- Maximum g-load
- Reaching target energy level

Solution

- Include a margin
- Change the flight profile during the descent

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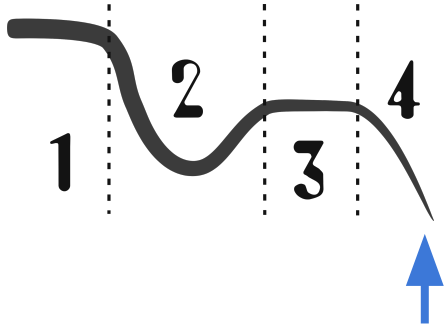
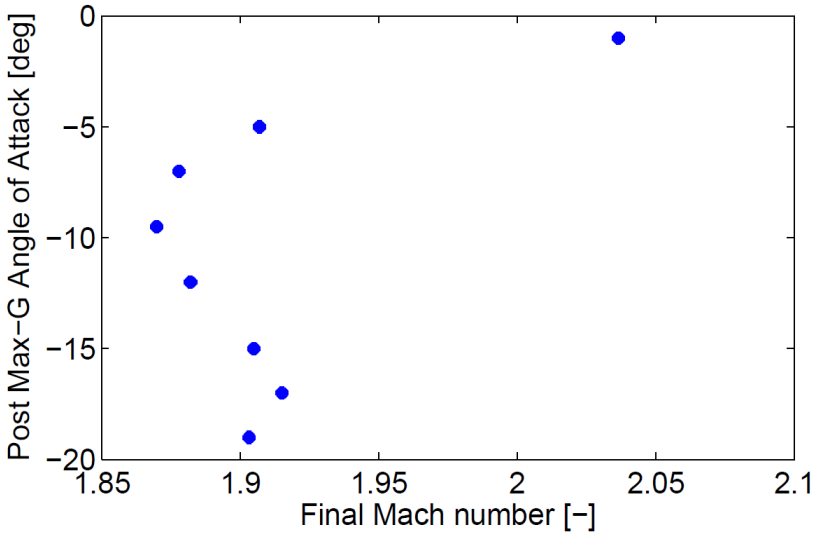
EDL - Design Drivers



Reaching the target energy level

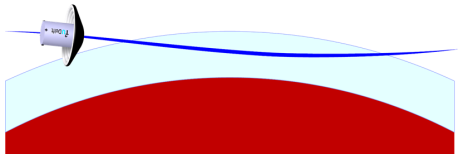
- Re-entry optimization



- Change the loads at critical points
  - After maximum g loads
    - Reduce lift, and also drag!
  - After skipping is impossible

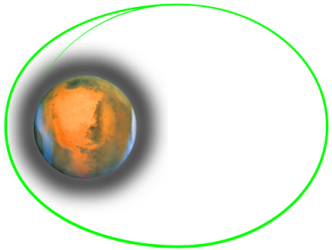
Summary

Aerocapture



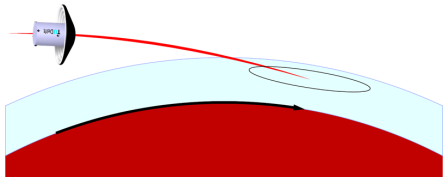
- TPS system

Mars Synch Orbit



- Exit conditions

EDL



- G-loads
- Target energy level

The preliminary study has shown that external center of gravity shift is feasible.

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Acknowledgements

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